94

OPINIONS

RELATIVE TO

THE HAUPT SYSTEM

—— OF ——

HARBOR IMPROVEMENTS.

Civil and Maritime Engineers, Hydrographers, The American Philosophical Society,
and others,

VS.

The Report of the Board of Engineers.

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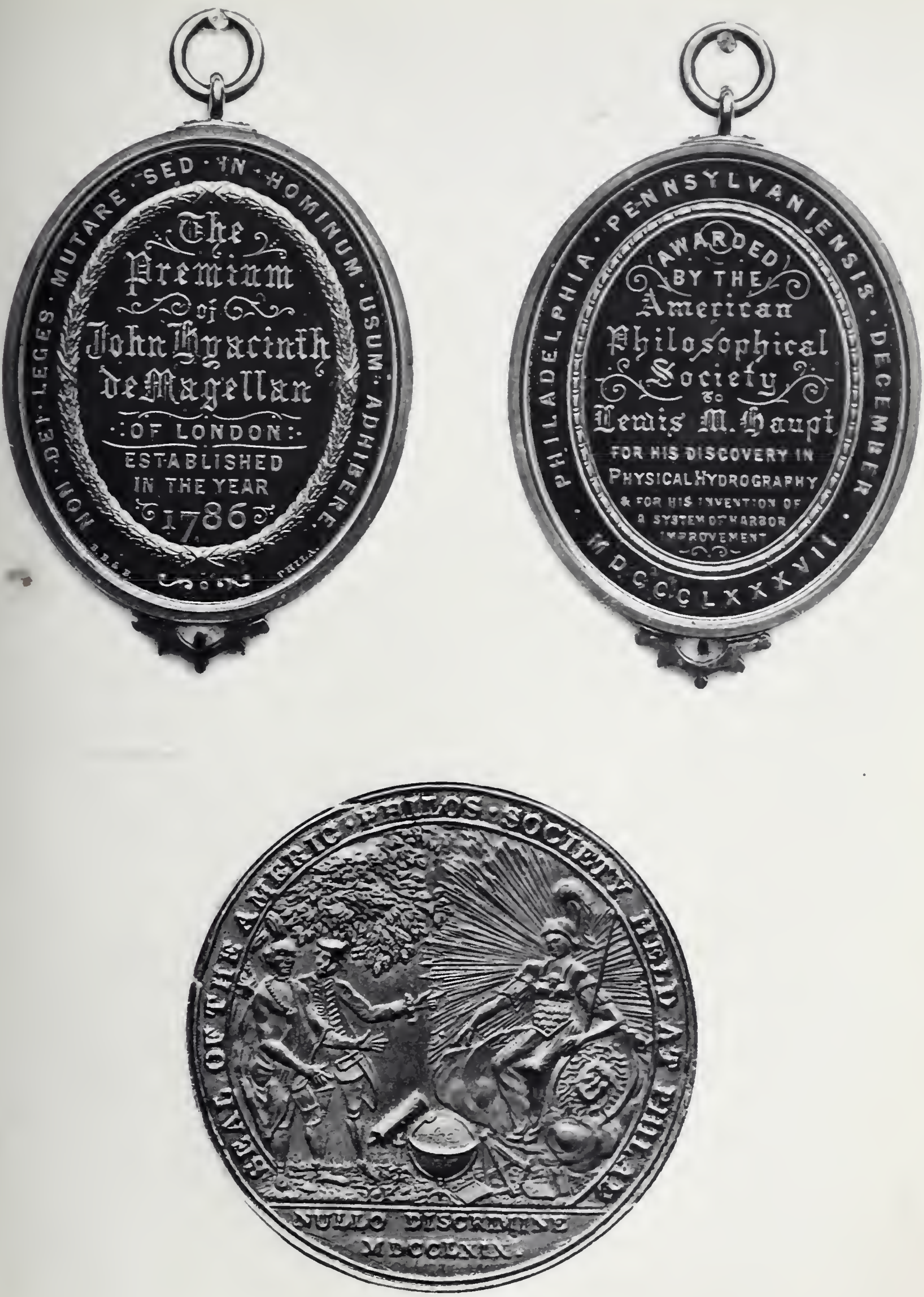
NON · DEI · LEGES · MUTARE · SED · IN · HOMINUM · USUM · ADHIBERE ·
The Premium of John Hyacinth de Magellan
· OF LONDON ·
ESTABLISHED IN THE YEAR
1786
PHILADELPHIA · PENNSYLVANIENSIS · DECEMBER · MDCCCLXXXVII
AWARDED BY THE
American Philosophical Society
to
Lewis M. Haupt
FOR HIS DISCOVERY IN PHYSICAL HYDROGRAPHY
& FOR HIS INVENTION OF A SYSTEM OF HARBOR IMPROVEMENT
SEAL OF THE AMERIC · PHILOS · SOCIETY HELD AT PHILAD
NULLO DISCRIMINE
MDCCLXIX

THE MAGELLANIC MEDAL

AND THE SEAL OF THE

AMERICAN PHILOSOPHICAL SOCIETY.

December 16th, 1887.

PHOTOTYPE F. GUTEKUNST PHILAD'A

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THE HAUPT SYSTEM OF HARBOR IMPROVEMENTS.

INTRODUCTION.

In presenting these opinions to the public, the author desires to state that, excepting the letter of Prof. Hilgard, they were not written with the expectation of being published, and hence he does not feel at liberty to append the names of the writers.

The importance of making a practical test of the principles embodied in the plans to which reference is made herein, and which have been so highly and generally commended by competent engineers, excepting those Government engineers whose official opinion has been solicited, would seem not only to justify, but to require the writer to publish this paper in the interest of a long-needed public improvement.

The commendations contained in these letters are, with very few exceptions, from persons unknown to the writer, and may therefore be accepted as disinterested expressions of opinion.

THE REQUIREMENTS.

This system, upon which their opinions are expressed, is based upon prevailing directions of sand movements found to exist at many alluvial inlets. It is so designed as to fulfil as nearly as may be the following requirements, viz:

(1) To keep out the sand carried up on the bar by the flood tide.

(2) To admit as large a portion of the flood tidal prism as possible.

(3) To prevent the advance of the fore-shore by the sand deposited in the groins (as occurs where jetties are used).

(4) To change the conditions of equilibrium of the flood and ebb currents over the same part of the bar.

(5) To prevent the dispersion of the ebb over a large section of the outer bar, and concentrate it along the line of least resistance.

(6) To construct a barrier of such form and position as not to generate injurious or destructive cross-currents and eddies.

(7) To leave an ample waterway and provide additional aids to navigation.

(8) To reduce the length of the breakwater, and consequent cost, to a minimum, and yet furnish a safe roadstead and harbor entrance.

THE STRUCTURE.

The general form of the breakwater is, in plan, a crescent, having a straight or slightly curved flank at its inner or shore end, and forming with the shore a funnel-shaped passage, through which the flood tide enters freely, but from which the ebb is restricted in its escape, and compelled to pass out over the bar in the lee of the structure.

THE PREMIUM.

It was for the discussion of the physical laws, and their application to the invention of this system, that the American Philosophical Society* awarded its most jealously guarded premium, by unanimously adopting the following report of the Committee appointed to investigate the merits of the paper:

In the opinion of the Committee, the claimant is entitled (*excepting with regard to certain fundamental facts as to tidal movement on the coast of the United States, which he himself has accepted and incorporated in his digest*) *to the merit of having not only clearly perceived and distinctly enunciated the laws concerned as the basis of his argument, but to that of proffering in connection with the statement of those laws, an invention contributive to the interests of navigation on a large portion of the coast of the United States, and wherever similar conditions may elsewhere prevail.*

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* This Society originated in the Junto, organized by Dr. Benjamin Franklin, in 1743, and which was merged with the American Society in 1768, since when it has been known as The American Philosophical Society.

Having in the opinion of the Committee accomplished this; having, according to the best lights obtainable by the Committee, thus acquired (barring qualifications noted in this report) the right of priority of discovery in a physical matter, coupled with an invention applicable thereto, useful through navigation to mankind, he has, in their opinion, in accordance with the purview of the conveyance of the Magellanic bequest to the Society, established his claim to the award of the Magellanic Premium.

(Signed.)

R. MEADE BACHE, *Chairman,*
(Assist. U. S. Coast and Geodetic Survey.)

THOS. M. CLEEMAN,
(President Engineers' Club of Philadelphia.)

HENRY WINSOR,
(President Winsor Line of Steamships.)
(President Board of Port Wardens, etc.)

A. E. LEHMAN,
(Civil Engineer and Geologist, 2d Geol. Survey of Pa.)

RUSSELL THAYER,
(Civil and Sanitary Engineer, Chief Eng. of Fairmount Park.)

The day following the annual vote on premiums, Mr. Frederick Fraley, the President of the Society, as also of the National Board of Trade, wrote as follows:

HALL AM. PHIL. SOCIETY.
PHILADELPHIA, *December 17, 1887.*

MY DEAR SIR:—*It gives me very great pleasure to inform you that at the Stated Meeting of the Society, held last evening, the Magellanic Premium was awarded to you for your paper on Harbor Entrances and improvements connected therewith.*

I sincerely congratulate you on this recognition of your skill, learning, and successful treatment of the important subject of your treatise, and hope that your suggestions may tend to the improvement of our great national waterways.

The premium has been awarded only twice in the last forty-five years, according to my personal knowledge, and its award to

you is therefore a matter of which you should be justly sensible.
With great regard, I am, Truly yours,
(Signed.) FRED. FRALEY, *President.*

Since the creation of the fund, October, 1786, the premium has been awarded to the following persons:

(1) To Dr. Francis Hopkinson, for his invention of a Spring Block in Navigation. Filed Dec. 18, 1787. Awarded Dec. 17, 1790.

(2) To Robert Patterson, for his improvements in Electrical Rods or Lightning Conductors. Filed Dec. 17, 1790. Awarded Dec. 21, 1792.

(3) To Dr. Wm. Thornton, Philosophical Dissertation on the Elements of Written Language (Universal). Filed Dec. 17, 1790. Awarded Dec. 21, 1792.

(4) To Nicholas Collin, Paper on an Elevator. Filed Dec. 2, 1791. Awarded Dec. 26, 1794.

(5) To Dr. Benjamin Smith Barton, A Number of the Pernicious Insects of the United States. Filed Nov. 16, 1804. Awarded Dec. 21, 1804.

(6) To Prof. Pliny E. Chase, Essay on the Numerical Relations of Gravity and Magnetism. Filed ——. Awarded Dec., 1865.

(7) To Prof. Lewis M. Haupt, Essay on the Physical Phenomena of Harbor Entrances, Their Defects and Remedies. Filed May, 1887. Awarded Dec. 16, 1887.

The awards can only be made annually, in December. There was also one pecuniary premium awarded to Prof. Jas. P. Espy, for his Theory of Rain, March 4, 1836.

Most of these awards were made only after two or three years of investigation by the Society.

The medal having been prepared in accordance with the designs of the Committee appointed for that purpose, it was presented formally at the stated meeting of the Society, held May 4, 1888. As the account of the ceremonies, taken from the *Public Ledger*, of the 7th, will be found to contain more than a personal interest, it is therefore inserted:

MAGELLANIC PREMIUM.

Awarded by the American Philosophical Society to Professor Lewis M. Haupt.

Last Friday evening (May 4th) the Magellanic premium, of which the American Philosophical Society is the trustee, was presented to Professor Lewis M. Haupt, of the University of Pennsylvania, "for his discovery in Physical Hydrography, and for his invention of a system of harbor improvements." The work which was thus so highly honored is embodied in Professor Haupt's recent publication on the "Physical phenomena of Harbor Entrances, their Causes and Remedies." In this work he has described the varieties of the shoals which form, almost without exception, at the entrance to tidal harbors, pointed out the physical peculiarities which cause them to form, and proposed a system whereby the very causes which, undirected, will cause shoals, may be so controlled as to prevent their formation, or to remove them when formed. The discoveries will, in all probability, prove of the highest importance to the Government, which yearly expends many millions of dollars in maintaining the harbors and removing the shoal and islands formed in them.

THE MAGELLANIC PREMIUM.

The Magellanic Premium was established in the year 1786 by John Hyacinth de Magellan, of London, who offered to the Philosophical Society as a donation the sum of 200 guineas, to be vested in a secure and permanent fund, to the end that the interest arising therefrom should be annually disposed of in premiums to be adjudged by them to the author of the best discovery or most useful invention relating to navigation, astronomy or natural philosophy (mere natural history only excepted).

The Society having accepted this trust, conditions were drawn up, prescribed by the donor and accepted by the Society, upon which the premiums should be awarded. According to these conditions, the candidate for the honor must submit his invention or discovery to the President or one of the Vice-Presidents of the Society, together with a device or motto, by which the author (whose name is not appended), may be distinguished. No restrictions are made as to nationality, sect or denomination of the candidate, but the invention must be novel and not previously publicly rewarded, and the communication must be in English, French, German or Latin. The communication, as publicly read, is open to the inspection of all the members of the Society. The communications so received are referred to the twelve counsellors and other officers of the Society, who report thereon at one of the stated meetings in December, and the vote of the Society is then taken as to whether any of the communications then under inspection is worthy of the proposed premium, and if this is decided affirmatively, which of those submitted is most useful and worthy. Unsuccessful communications remain under consideration for five years, except such as the authors see fit to withdraw, and if still unsuccessful at the end of five years, the communications, together with the key to their authorship, is burned by the Society.

THE PRESENTATION CEREMONIES.

It will be seen that the value of the premium thus publicly awarded by the venerable and world famous Philosophical Society is very much greater than the intrinsic worth of the gold medal which is presented the successful candidate. In December, 1887, the premium was awarded to the communication submitted by Professor Haupt, and the presentation of the premium was made last Friday at a meeting of the Society in the old building adjoining Independence Hall.

PRESIDENT FRALEY'S ADDRESS.

Prof. Haupt, it is a great gratification to me, both personally and officially, to present to you the Magellanic Premium, which has been awarded by the

American Philosophical Society for your essay on "The Physical Phenomena of Harbor Entrances, their Causes and Remedies." This essay treats of matters of great national importance, and your discussion of them will greatly tend to the improvement of the methods now in use for effecting the permanent removal of the obstacles in our harbors and rivers, which are so dangerous to navigation and are so full of risk to the lands and buildings along their shore lines. A glance at the map of the United States will show the great number of our navigable rivers and the vast extent of coast lines, and their valuable and important harbor entrances. And it is therefore important that the money appropriated for their improvement and enlargement shall be wisely and scientifically expended. I think your suggestions will be found very valuable in securing stability to all artificial structures that may be erected in our great waters for their protection and convenient use, and you are therefore entitled to be honored as a public benefactor. The Magellanic Premium was established in the year 1786, and the records of the Society show that only six awards of the medal and one honorary pecuniary premium have been made within the century. Yours is therefore the seventh premium. It is thus shown that the terms under which the premium can be claimed are difficult to be met, but you have filled them, and I sincerely and cordially congratulate you on your success.

Prof. Haupt made the following reply:

Mr. President and Fellow-Members of the American Philosophical Society: —Accepting this estimable token of approval, which this distinguished Society has conferred upon the results of my investigations, it gives me great pleasure to express to you my grateful obligations for this unusual mark of approbation.

The conditions accompanying applications for the Magellanic Premium being such as to eliminate entirely all personal elements, I felt that the opportunity of obtaining a critical and impartial investigation of my researches was thus admirably presented, and that no more competent body, organized for scientific research, could be found to pass judgment upon a matter which I deemed of great importance to the commercial, scientific and engineering development of our country.

I was pleased, therefore, to embrace this opportunity of presenting the paper on "The Physical Phenomena of Harbor Entrances" to the American Philosophical Society for consideration and action. Whatever value the paper may have, the weight and influence it may exert in the future, in modifying the plans for meeting the difficult requirements of maritime works, are chiefly due to the careful and deliberate consideration which your Society and committees have given to the subject; and, deeply as I feel the honor, as well as the responsibility which this approval of my labors places upon me, I earnestly hope you will permit me to state that, whatever may be my share of the merit conferred, it is but the reflection of that emanating from yourselves as members of this learned Society.

To me your endorsement is at this time particularly encouraging, for already I find myself in the position of the pioneer who breaks loose from the well-trodden highways and seeks to discover a new path through the trackless waste. His task is full of responsibility, and he needs to keep well in view his landmarks; sometimes ahead, at others behind him. So I find myself looking back for my bearings whilst I am pressing forward toward the goal, which is the introduction of these plans at some suitable port of entry along our coast.

The difficulties which I expected to find, and do find, in this effort are those resulting from conservatism and inertia of the Government machinery; but they are inherent to all development and furnish additional evidence of the soundness of the conclusions you have already reached. It is, therefore, with peculiar satisfaction that I look upon this medal, the seal of your approbation, not as upon an *ignis fatuus*, to lure me on to destruction, but as a talisman to encourage me in pursuing the way I have taken as one leading to a laudable end.

The discussions, which opposition must provoke, should result in elucidating more clearly the principles embodied in these physical studies and in removing them more and more from the domain of theory and planting them upon the firmer foundation of fact.

By this means they will be brought to the knowledge of the unprofessional reader and receive the support of those most directly interested in their application.

I have observed that in dealing with physical questions, involving only inert matter, the problems are comparatively simple, whilst those of a social character, which enter the domain of mind, become exceedingly complex; yet these two classes appear to be almost inseparably related. In developing an engineering project, the first stage is that of mental conception and evolution; the second, that of education and propagation; and the third, that of execution or construction. It is in the second stage where the greatest difficulties are encountered, for it is always a difficult task to undertake to modify prevailing impressions. The contest is an unequal one, but when the changes proposed are based upon and allied to truth, they must ultimately prevail. Otherwise, they must as certainly fail, and this is therefore the crucial stage.

A distinguished philosopher says: "The best way to come to truth is to examine things as really they are, and not to conclude they are as we fancy of ourselves, or have been taught by others to imagine."

If we could but lay aside previous impressions and prejudices it would be an easy matter to apply this advice to see things "as really they are," but, unfortunately, judgment is too often blinded by habit or education. This prevalent propensity of accepting statements without investigation, or of reaching conclusions from superficial observations, has led mankind into many errors which can be removed only by searching and impersonal discussions. Such discussions, therefore, should be welcomed as tending to the perfection of knowledge and the revelation of truth.

The studies which I have submitted to you have been my recreation and delight, and in pursuing them I have realized the truth and beauty contained in these lines from "Thalaba:"

> "Learn thou, O young man,
> God hath appointed wisdom the reward of study!
> 'Tis a well of living waters,
> Whose inexhaustible bounties all might drink,
> But few dig deep enough."

The treasures of wisdom are only to be unearthed by digging deeply, and I believe it accords with the experience of every investigator, that the deeper he delves the more treasure he discovers. Especially is this true when applied to investigations relative to the laws of the physical world, and, as each increment of knowledge is added to that already gleaned, the mind of the devout student becomes more and more fully impressed with the sense of his own impotence and of the infinite majesty and wisdom of Him who, from the beginning, conceived, created and continually maintains the universe; to whom belongs all the glory, praise and honor of our feeble efforts forever.

This idea of our dependence upon the Supreme Being your committee have very happily embodied in the motto which they have placed upon the medal: "*Non Dei leges mutare, sed in hominum usum adhibere.*"

THE OPPOSITION.

Before this award no publicity could be given to the matter, in consequence of the requirements of secrecy as to the authorship of the paper, but as soon thereafter as possible (viz., January 17th), the request for a hearing was granted by the Board of Engineers, U.S.A., in New York, four members being present. Two months later, or on March 16th, the Board made their report to the Chief of Engineers. In concluding it, they find that Prof. Haupt's views "are purely theoretical, unconfirmed by experience, and contain nothing not already well known, which has a useful application in the improvement of our harbors."

This report was signed by a majority of the Board, and as it called for precedents, a reply was printed, containing a discussion of the various statements of the paper, and answering them *scriatim*. This was mailed to the Chief of Engineers June 30th, with a letter of transmittal. As no acknowledgment was received, and as there had been, in the meanwhile, a change in the Chief Engineer, a second letter was sent on July 30th, calling attention to the papers and requesting an acknowledgment. No response to this being received, a third letter was dispatched September

14th, with duplicates of the papers, and a copy of the Discussion was also mailed to five members of the Board. To these several communications no response has been received, nor have they ever been acknowledged. The following is a copy of the letters sent:

DEPARTMENT OF CIVIL ENGINEERING,
UNIVERSITY OF PENNSYLVANIA.
PHILADELPHIA, September 14, 1888.

Col. T. Lincoln Casey, Chief of Engineers:

DEAR COLONEL:—As I have received no response to my letters of June 30th and July 30th, transmitting a copy of my Reply to the Board of Engineers, I can only assume that those letters and papers were not received, and hence I take the liberty of remailing a copy of the Reply to you, with an enclosed transcript of my letter of June 30th to Gen'l Duane, then Chief of Engineers.

I will also mail copies of the Discussion to the members of the Board, and would be pleased to receive the names of the new members for that purpose.

I have also to extend my congratulations upon your accession to the highest honor in the Corps.

Very respectfully,
Your obedient servant,
LEWIS M. HAUPT.

[COPY.]

JUNE 30, 1888.

Gen'l Jas. C. Duane, Chief of Engineers:

DEAR GENERAL:—I have the honor to forward herein a printed copy of my Reply to the Report of the Board of Engineers, to whom was referred my paper on the new plans for improving harbor entrances. The preparation of this paper has been unavoidably delayed and, as the precedents the Board desired are few and have required much research to find, the work has been slow.

As the data thus collated will be of service to the profession of engineering generally, I have embodied it in printed form for the clearer and more permanent preservation of the subject-matter.

I do not find that the wind-wave theory satisfactorily accounts for the changes that are so constantly taking place along the coast, and I believe that the policy adopted in some of the districts, of holding the receding spit, without at the same time checking the advancing one, will prove injurious to the inlets and add to the expense of the works.

I regret that I do not find myself in harmony with the views of the majority of the Board on this important question, and trust that this additional evidence, which I have been called upon to produce, may have due weight in bringing us nearer to the truth.

At all events, since I believe my plans to be new, and hence unprecedented, it would doubtless be satisfactory to the Board, as well as to myself, if an opportunity were given me, to make a test, or to be referred to a similar construction which has failed. If there be none, it would be a valuable contribution to the profession to have a record of the facts, from experience.

I have, therefore, the honor to request that you will recommend, with the approval of the Board, if you so desire, that a trial may be made, at a site to be agreed upon by the parties interested in securing deep water.

I have the honor to remain, sir, Very respectfully,
Your obedient servant,
LEWIS M. HAUPT.

Concerning this "DISCUSSION," or Reply to the Board, a prominent hydrographer, who is unknown to the writer, says:

"It seems to me that your replies to the objections of the Board to your plans will be received as satisfactory by unprejudiced persons. My opinion, however, is that the opposition of the corps to your paper is not on account of its *defects*, but rather on account of its *merits*."

An experienced civil engineer, in discussing the plans, writes:

"In regard to Prof. Haupt's practical recommendations for New York Harbor, Charleston Harbor, etc., I believe that the breakwater across the shoal would act beneficially in serving as a barricade against sand as well as high waves and in increasing the force of the ebb current in the channels across the bar. I also believe the curved form commendable."

A gentleman, interested in transportation matters in Texas, realizing the great necessity for immediately securing a port on that coast, writes:

"The question of deep water at some point on the Texas coast is now agitating the people. * * * I hope you will forgive the liberty I take with yourself, your writings and your plans, the only excuse I can offer is that I am so impressed with your knowledge of the coast and ocean dynamics, and so convinced that yours is the only feasible plan by which deep water can be obtained, that I have been gradually drawn into the discussion before I realized how much was due to you."

An engineer, for many years employed on a difficult piece of harbor work, writes from Missouri:

"I have been so much occupied with other matters that I have not yet had time to make any comments on your jetty pamphlet. But I will say that I think so favorably of the principles therein stated, that if I were in charge of new work for improvement of such harbors as you mention, and free to follow my own wishes, I would certainly make a trial on the lines you indicate. The result could not be any worse than that of present practice, and I think there is every reason to expect a marked improvement."

At a later date, in commenting on the Discussion and Reply to the Board of Engineers, he says:

"I think that one of your strongest arguments, if not the strongest, is that of the periodic character of the movement of the flexed ends of the channels. I consider that you have made a valuable contribution to the literature of maritime engineering. I cannot see how anyone can fail to be convinced of the general correctness of your views and the feasibility of your plans for improvement of alluvial harbors. I hope that you may have an opportunity to test them, and that you will be successful."

A maritime engineer and physical hydrographer of great experience on the Lakes and the Gulf of Mexico, writing from Michigan, says:

"You have covered the ground so thoroughly in your 'Discussion,' that it seems to me that additional argument is uncalled for. The investigator who still finds no principles worthy of his consideration in the presentation you have made, will, I think, be very hard to convince. You have shown very clearly that many of the phenomena, of which the Board have entirely failed to understand the causes, are only so many links in the chain of facts on which you have based your statement of causes of existing characteristics in bar formations."

The following extracts from prominent citizens and engineers are submitted as representing the opinions of authorities as to the possibility of obtaining a deep-water harbor on the Gulf Coast by the methods at present pursued by the U. S. Engineers:

"The South Jetty is now (1888) being built, at Galveston, of rip-rap and large blocks of stone, with a clay core,* but the present appropriation will not carry it out more than about a mile and a half, and no result is expected."

"The sentiment is becoming very general that deep water is of so great import that the State must take hold of the work and not rely on the Government driblet system, which offers no hope for good results. I share with you the apprehension that the present work (at Galveston), when completed, will again end in failure."

"An engineer in charge claimed that his works had deepened the water on the outer bar *2 feet*. He commenced with 12¾—ended with 12¾, and no survey ever showed more than 13 feet at mean low tide."

"Now, as to the inner bar—look at the report again—as a *result* of the Government works, it says, the water has increased to 20 feet. This is inexcusable. The facts are: In 1872, there was only about 12 feet on inner bar. Storm of 1875 cut it out, and when the officer took charge there were over 20 feet—and has been since 1875. There was no *inner* bar until after 1850 (?), shoaling commenced after this and in 1866 there were only 9 feet on *inner* bar. The city of Galveston appropriated money, drove piles, and, in 1872, there were 12 feet of water, an increase of 3 feet, the result of City's work and not of Government engineers. The storm of 1875 (not works of City nor Government, for none were left) obliterated the inner bar and shifted the channel."

Another says:

"The plans proposed by the Board of Engineers for Galveston I believe to be thoroughly bad; and if carried out to completion will have an insignificant effect on the bar. The exterior work proposed by you, as indicated on the chart, is better, but I am uncertain as to the result to be expected from it. Accepting your theory, which I do, of a 'flood resultant' from the northeast, the action of your structure would be to protect the ebb from it, leaving the ebb to select its own channel. The idea of an *interior* reaction dike is excellent. I have been very much interested in your paper and it is almost needless to say that I think it is very valuable."

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* This core is omitted from the later contract (October, 1888).

Again:

"Your paper on the Physical Phenomena of Harbor Entrances has been received, for which please accept my thanks. I regard it as the most valuable contribution to the science of hydro-dynamics which has appeared in recent years. It is my opinion that a single curved jetty, properly located on the north side of the entrance, would give better results than can ever be obtained by means of two straight jetties. Your demonstration of the error relating to the quantity of discharge, after the construction of jetties and the equilibrium restored (by the plans attempted at Charleston, S. C.), is complete.

"The plan which is now being prosecuted at Galveston is one proposed by the Board of Engineers, in a report dated January 21, 1886, and which, if carried out, will result in a greater failure than either of the preceding."

"Your discussion of the Physical Phenomena of Harbor Entrances is especially interesting, as it is the first attempt, so far as I know, at any generalization concerning the causes which produce the peculiar forms of the harbors and inlets along our sandy coasts. I think that your conception of 'flood resultant' is novel, and that there is much to be said in its favor."

The following opinion is from a U. S. Engineer officer, in charge of an important district of harbor improvements.

His experience in tidal waters is believed to be limited to the past year and over, during which work has been largely suspended in consequence of the failure of the appropriation bill in March, 1887:

"I have received the copy of your paper upon Harbor Entrances sent me, with the request that I give you my opinion thereon.

"It is distasteful to me to offer adverse criticisms of a laborious and thoughtful paper such as this. The first part of it is an interesting and meritorious study. The practical conclusions, however, are wholly at variance with my convictions. I presume that I shall have to give my views upon it, in detail, in an official report. I fear they will not be agreeable to you."

As the opinions have not yet been publicly stated, no conclusions can be reached as to their bearing or importance, but they would probably be offset by those of the late Superintendent of the United States Coast and Geodetic Survey, whose life has been devoted to these physical researches, as expressed in his letter of May 20, 1888, as follows:

"1349 L St.
"WASHINGTON, May, 20, 1888.

"*My dear Prof. Haupt:*

"I have received your interesting paper on the 'Physical Phenomena of Harbor Entrances,' in which you describe the peculiar forms of the bars and spits found at the inlets along the sandy cordon of islands defending the Atlantic coast line, and give your explanation as to the forces producing them; ascribing them chiefly to the energy of the flood tide as affected by the general form of the coast line.

"In this I think you are entirely correct, as it is undoubtedly the unceasing activity of the flood that produces the forms which are so characteristic of harbor entrances, and not the wind waves produced by prevailing winds. The direction of motion of the beach sands is, as a rule, the same as that of the flood tide along the shore. It is modified by great storms, but only temporarily, and in a short time the flood reasserts its supremacy and the channel returns to its normal position.

"In applying this physical fact to the plans for improving the bars, I believe you have proposed the best form to resist the encroachment of the sand and yet admit the flood tide freely. These are fundamental conditions, and you have fully met them, while providing, at the same time, ample facilities for navigation.

"The successful operation of your proposed plan is well illustrated by the accidental experience with the stone fleet on Charleston Bar, described in my paper on 'Tides and Tidal Action in Harbors,' published in the Smithsonian Report for 1874. From that instance it is seen that by obstructing the inflow of sand and inducing an ebb current, two good channels were formed, the better one to the leeward of the obstruction. Your plans would change the conditions of equilibrium in favor of the ebb, and the length of your breakwater is much less than that required by existing methods.

"I trust that they will be tried at some suitable entrance along the Atlantic or Gulf Coast.

"Yours with great regard,

"J. E. HILGARD."

TO PROF. LEWIS M. HAUPT,
UNIVERSITY OF PENNSYLVANIA.

A prominent and successful contractor for hydraulic and marine works, writes from New York:

"I have read the paper you sent me with great interest. I know the plan you advocate will work," etc.

The casual reader will observe that the only adverse opinions are those from the Government Engineers, who have been called upon for an expression of their views, and it is difficult to explain why these officers of the Government should oppose a method of improvement which, so far as they are aware, has never been tried, yet which gives so great promise of success; and why they should adhere so persistently to a method which all maritime engineers of experience acknowledge to be but an expensive and unsatisfactory expedient, costing large sums of money to maintain.

In confirmation of the requirements heretofore stated, that the jetty should be on the side toward the flood component, reference is made to the experience of a private company, at Aransas Pass, on the Texas Coast, in 1869.

Here the movement of sand is *southward* at the rate of over 200 feet per annum, and this company expended less than $10,000 in building a short jetty only 600 feet long from the *north* shore and extending out on the *north* side of the channel.

"These jetties, crates or caissons, as they are variously called by the builders, were made of live-oak poles, spiked together in the general form of a triangular prism and placed longitudinally. Each crate was about 8 or 10 feet long, 6 feet high and 6 feet wide at the base * *. They were ballasted with a few hundred-weight of stone, filled with brush and sunk in two or three parallel rows. They were expected to act as a nucleus about which the sand would settle, and close up the secondary channel, thus directing the flow of water directly through the channel of the bar. From the fact that the secondary channel has shoaled about two feet, and the main channel deepened about two feet since placing the crates, it may be supposed they have contributed to produce this result."

In a later report dated February 1, 1879, Maj. Howell, then in charge, in commenting upon this early precedent, remarks, "From my remembrance of a verbal description of the work * * *, the cribs were triangular in cross-section (dimensions not known), and their parts were very imperfectly fastened together, and besides seem to have been made of any timber and lumber that came handy—some live-oak, but mostly yellow pine scantling, 4 inches by 6 inches.

"Some of these cribs were filled with brush and stone when sunk in place, but it is said that others were simply ballasted so as to sink them. During the work of construction some of the cribs near the shore were broken up and washed away.

"When the work was suspended it is said there was a twelve-foot channel across the bar, which was maintained for several months, possibly until the teredo and the waves had destroyed a considerable part of the frail crib-work.

"In 1871, when the late Lieut. E. A. Woodruff made a reconnoissance of the pass, he was unable to find any trace of the work. It is said that as the work gradually disappeared the channel across the bar gradually returned to its normal depth. I consider my information reliable as to the above described work and its effects."

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* Report of the late Lieut. E. A. Woodruff, Corps of Engineers, dated April 1, 1871, *vide* Report Chief of Engineers, 1871, p. 526.

These extracts show very conclusively that, so far as this frail structure went, it was in the proper place, and did effective work in improving the channel by keeping out the sand and preventing the dispersion of the ebb. Its form and materials might have been improved to great advantage.

The Government failed to profit by this precedent, however, for in August, 1887, the engineer officer in charge of this pass reported that—

> "The work designed to deepen the channel over the bar, consisting of a single jetty, constructed upon the south side of the entrance, has had no important effect upon the bar, and is in a dilapidated condition. The channel depth, over the bar, is now eight and one-half feet, and the channel crosses the jetty."

Thus, it appears that this jetty was attempted on the wrong side (the south) of the channel, and that the ebb discharge in seeking the line of least resistance was forced over the crest of the submerged work by the bar of sand rolled up by the flood component.

JETTIES IN PAIRS.

This paper would be incomplete without the evidence collected by experienced maritime engineers of other countries, as to the results of similar works elsewhere.

In his digest of jettied entrances, Sir Vernon Harcourt says in general of the jetty system:

"The jetties also, in most cases, were extended in the hope of reaching deep water, which proved fruitless, owing to the progression of the foreshore with each extension of the jetties. Next, artificial sluicing basins were formed, to provide a larger mass of water for sluicing, with the additional advantage that the issuing current was nearer and better directed for scouring the entrance. Lastly, dredging with sand-pumps is being largely employed for deepening the channel beyond the jetties. The parallel system has not proved successful in providing a deep entrance without constant works. * * Experience has shown how jealously encroachments on the tide-covered lands should be prevented, and the uselessness of prolongations of the jetties. * * Parallel jetty harbors are one of the most difficult class of harbors to design and maintain successfully."

Again, the President of the Institution of Civil Engineers of Ireland, and Engineer of the Port of Dublin, J. Pursur Griffith, writes with reference to the alluvial harbor at Ostende :

"It is not necessary to enter into a detailed description of the successive additions made to the jetties and sluicing reservoirs * * suffice it to say, that the jetties extend at present about 300 meters seaward from the shore line, and the maximum sluicing capacity of the reservoir is about 1,100,000 cubic meters. The result of these costly works cannot be regarded as satisfactory. The channel is still shallow, while the bar a short distance beyond the pierheads still forms a dangerous obstruction. *Depth of water at the entrance to a port is more needful during rough, wild weather, than in calm, and it is just at such times that sluicing operations similar to those at Ostende fail.*"

Speaking of the jetty system in general, he says:

"The system, so generally adopted in Continental ports, of parallel or nearly parallel jetties, extending only to comparatively shallow depths, appears to be radically wrong in principle. Their tendency, generally, is to act as groins, and make the sandy shore extend outwards until the sand passes around the pierheads where the action of the sea heaps it up in the form of a bar."

It seems unnecessary further to multiply instances of the failure of the principle of parallel jetties in tidal waters, and it is confidently believed that the single-curved barrier placed upon the bar as an obstruction to flood-wave and sand movement will be found to fulfil the requirements of these problems better than by any plans hitherto invented.

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